[Return to VK3YE amateur radio projects]

A simple crystal set for free power radio

Of any electronic project, the crystal set would have to rate as one of the most popular. Many amateurs are on the air today because of their early construction of a crystal set. Most practical electronic books for beginners include at least one crystal set project. Unfortunately, some of these circuits take simplicity too far and deliver mediocre performance, often by omitting key components such as the tuning capacitor, or failing to provide coil taps.

This article describes a crystal set of medium complexity. It features coil taps for the antenna and diode to make it useful for both country and metropolitan listeners. The taps allow the set to cover 160 metres if desired. All parts are easily obtainable, making it a good choice for the beginner. The endless possibilities for experimentation also make crystal sets interesting novelty projects for experienced constructors. The schematic is shown here:

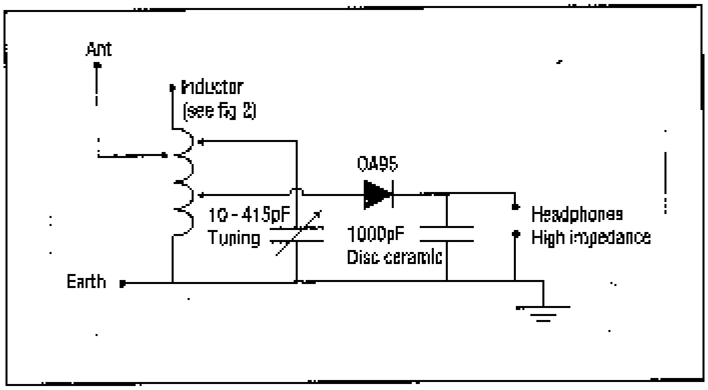


Figure One: Schematic diagram of crystal set

VK3YE Crystal Set

Schematic & Layout diagrams

Press Back button to return to main article

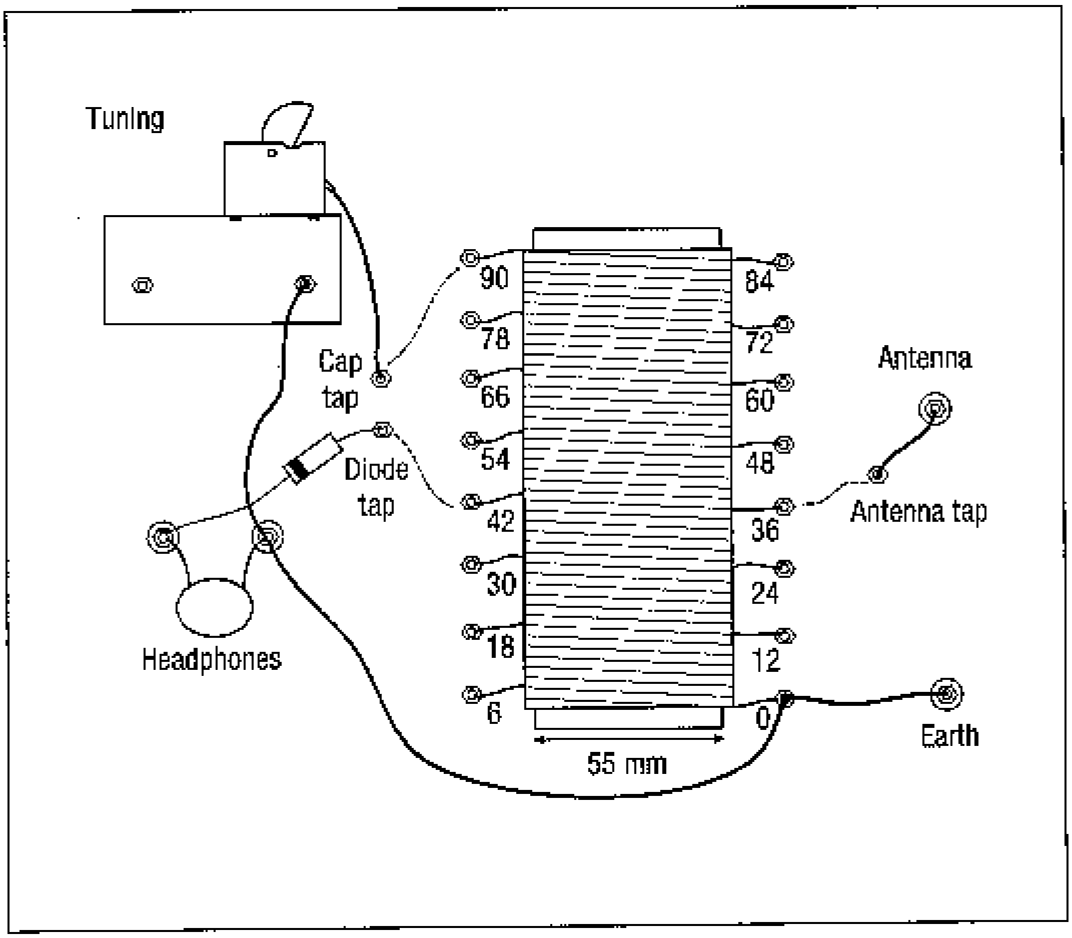


Figure Two: Rear view of front panel, showing coil details

(from Amateur Radio February 2001, page 20)

Obtaining the parts

Tuning capacitor

A large air-spaced type, covering about 10 to 415 picofarads is preferred. These capacitors were common in valve and early transistor radios and often appear at hamfests. Their long shafts make it easy to attach large tuning knobs. When purchasing one see that the shaft turns freely, but is not loose. Ensure that the plates are straight and do not touch when meshed - use a multimeter (preferably with audible continuity function) to test this. Avoid capacitors with 3/8 inch shafts unless nothing else is available â€“ knobs for these are not obtainable, and an old valve radio dial drum will need to be used instead.

If a large capacitor is unavailable, a small plastic dielectric unit is suitable (such as stocked by Jaycar and online). The lower maximum capacitance (160 pF) means that more coil turns are required to provide coverage of the lower end of the broadcast band. This can be partially overcome by connecting the 60 and 160 pF sections in parallel (link the 'A' and 'O' tabs). The main disadvantage of these capacitors is their short shafts, which makes it harder to attach most types of knobs.

Vernier Drive and dial

The use of a vernier reduction drive is not necessary. However, its inclusion makes tuning easier, particularly on the higher frequencies. These are rare new but sometimes come up at hamfests. If your drive lacks a dial, one can be fashioned from a plastic or metal disc, such as a jar lid or salvaged computer hard disc. Glue the dial directly to the skirt of the tuning knob if you lack a vernier drive.

Diode

This is the most easily obtainable and cheapest component in the project. A germanium diode, such as a 1N60, 0A90, 0A91, 0A95 or 1N34A will be suitable. The purists still make their own diode detector with a 'cats whisker' and lump of galena, but modern diodes provide more stable and repeatable performance.

Headphones

The very old high impedance headphones are required for this circuit. A minimum of two kilohms is suggested. Medium impedance headphones (approx 600 ohms) will also work, but are less sensitive.

High impedance headphones have become difficult to obtain. Alternatives include:

1. Old-style telephone earpiece. Quite sensitive. Found in the old Telecom corded phones.

2. Crystal earpiece. These are sensitive, easy to obtain and inexpensive. You may need to connect a 100k - 470k resistor in parallel for it to work properly.

3. Piezo transducer. Believe it or not, these actually will work as an earphone. Some sizes even fit snugly in the outer ear in a similar manner to modern earpieces, such as used with mobile phones. The main drawback with transducers is their peaky audio response. Â In some cases it may be necessary to wire a 100k - 470k ohm resistor across the earphone connections for correct operation.

4. 1k to 8 ohm audio transformer and standard low-impedance headphones. Works well, but not as sensitive as a crystal earpiece.

5. Cheating! Use a transistor or IC amplifier kit to run a speaker. This approach eliminates the 'free radio' advantage of the crystal set, but provides louder reception in weak signal areas and allows speaker listening.

Coil and Coil former

This needs to be a cylinder about 55 millimetres in diameter and 150 mm long. The length needs to be long enough to accommodate all ninety coil turns used, with enough left over for mounting to the front panel. Plastic pipe, shampoo container or similar will suffice. Though enamelled copper wire can be used for the winding, the prototype used thin plastic-covered stranded insulated wire.

Front panel

All parts are mounted on a 6mm-thick polyethylene chopping board, which forms the front panel. A hacksaw was used to cut the panel to fit inside the wooden case. Use the thinnest chopping board available so that the many screw-mounted sockets used can be fastened properly. The front panel pictured was cut to 240 mm square.

Case and handle

Use non-metallic material for the enclosure. The box used in the prototype was originally a speaker bought cheaply at a school fete. The lid (which held the speaker) was removed, and the rest of the box painted. The top carry handle is optional and came from a hardware store.

Construction

Commence construction once all components have been obtained. Plan how the parts will fit behind the front panel. The diagram and pictures above show the arrangement used in the prototype. The coil is fastened with stand-offs and the variable capacitor is screwed to an aluminium L-shaped bracket. 4mm binding posts with banana sockets are used for the antenna and headphone connections, and 2mm micro sockets for the coil tapping points.

Start by winding the coil. This consists of ninety turns of thin stranded insulated wire close wound on a plastic tube approximately 55 millimetres in diameter. A large number of tapping points are provided so that the user can vary the set's frequency coverage, and antenna and diode coupling. This makes it possible to obtain the best compromise between volume and selectivity for a particular station.

Figure Two shows the coil construction. Start from the earth end (identified as '0' in the diagram). Make two holes in the former to anchor the end of the wire. Wind six turns and then an extra half-turn. With a knife remove about 1cm of insulation, taking care not to cut the wire. Form the bare wire into a loop and lightly coat with solder. Do not apply excessive heat - the wire insulation easily melts. Wind another five and a half turns and make another tap. Repeat for the remainder of the coil until approximately ninety turns have been wound. Add more turns and taps if using a smaller variable capacitor than specified. Again make two small holes in the former to anchor the wire.

Place the completed coil aside and start work on the front panel. Mount the 4mm banana binding post terminals for the antenna, earth and headphones, as shown in Figure Two. Drill holes and mount the 2mm terminals for the coil taps and the antenna, diode, variable capacitor taps. The tuning capacitor can also be fastened at this time.

Two sets of screws and spacers can be used to mount the coil to the rear of the front panel. A 10mm separation between the coil and the panel is adequate. Solder in the various components and connecting wires as per Fig 2. Use insulated wire for the connections between the sockets and to the variable capacitor. Tinned copper wire can be used for the short links between the coil taps and the 2mm sockets. Use insulated wire for the three jumper leads. The jumpers should be sufficiently long to be able to make connections with all taps along the coil.

This completes the construction. The panel can now be inserted into the box. In the unit pictured, the front panel is recessed â€“ this protects the banana sockets and dial and makes the set more rugged. It also allows attachment of a hinged lid if required.

Parts List

* 10 â€“ 415 pF variable capacitor x1 (see text)

* 0.001 uF disc ceramic capacitor x1

* 1N60 germanium diode x1

* Vernier dial or drive x1 (optional)

* 2mm micro socket x19

* 2mm micro plug x6

* Banana socket (red) x2

* Banana socket (black) x2

* Insulated wire 20m

* Tinned copper or bell wire 1m

Other items: case and handle; polyethylene chopping board; Coil former â€“ 55mm dia, 150 mm long; screws, nuts, washers and spacers; mounting bracket for variable capacitor.

How it works

To receive signals, a radio circuit must perform three functions: selection, detection and reproduction.

The inductor and variable capacitor form a tuned circuit. The role of the tuned circuit is to select one of the many signals present at the antenna. The size of the inductor and capacitor determines the frequencies that can be tuned. The

capacitor is made variable to allow the full range of AM broadcast band frequencies (531 to 1602 kHz) to be received.

The diode detector converts the selected radio frequency signal to an electrical current varying at audio frequencies.

The headphones convert this audio frequency energy to sound. The principle is similar to a relay â€“ the signal cause current to flow in a winding that forms an electromagnet. The magnetism generated vibrates the metal diaphragm, thus creating sound. Crystal earpieces perform the same function, but rely on the piezo-electric effect.

Unlike in a conventional radio, which uses amplifying devices such as transistors and integrated circuits, crystal sets are powered by the signal from the incoming station, so no batteries is required. If provided with an efficient antenna and earth, crystal sets can receive signals thousands of kilometres away.

Antenna and earth

A crystal set requires a wire antenna to operate properly. The longer and higher it is the better. A length of at least 10 metres in urban areas, and 20 â€“ 30 metres elsewhere should provide reception in most cases. The antenna should always be installed away from power lines for safety reasons and to reduce interference pick-up. An existing amateur or TV antenna can also be effective, especially if the coaxial feedline is used as part of the antenna. This is achieved by connecting both the outside and the inside of the coaxial connector to the receiver's antenna terminal.

An earth provides stronger signals, and is essential in remote areas. In homes with copper water pipes, this can simply be a lead to the nearest cold water tap. In newer homes, where plastic pipes are used, an outside ground stake can be used instead.

For long distance reception (hundreds or thousands of kilometres) more than usual effort needs to be taken when installing the aerial and earth. Reference One suggests a length of about 100 metres and a height of at least 12 metres. A series of buried radials is suggested for the earth, rather than the water pipe suggested above.

Operation

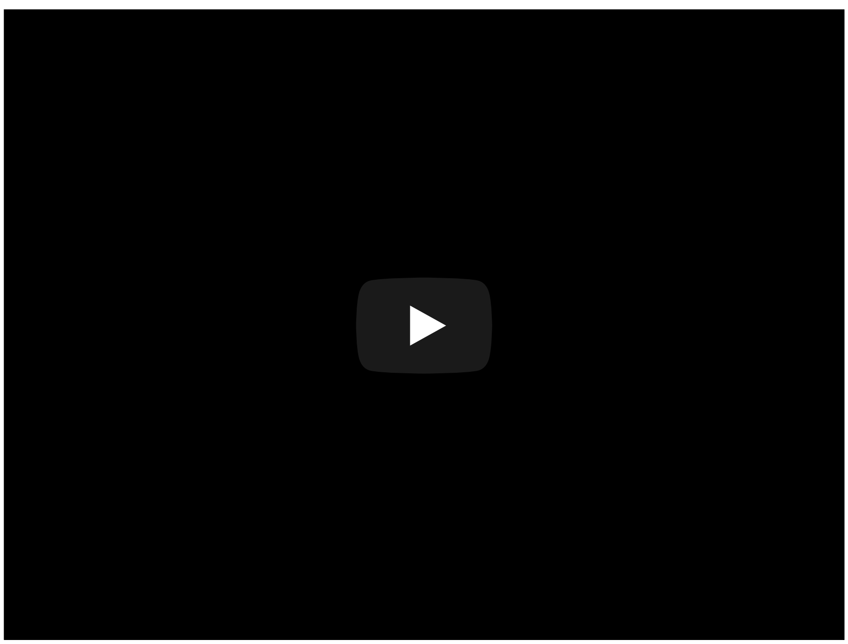
Connect antenna, earth and earphones. Install the three jumper leads. Set the capacitor tap to near the top of the coil (either the 78th or 90th turn) and the diode and antenna taps to approximately midway along the coil.

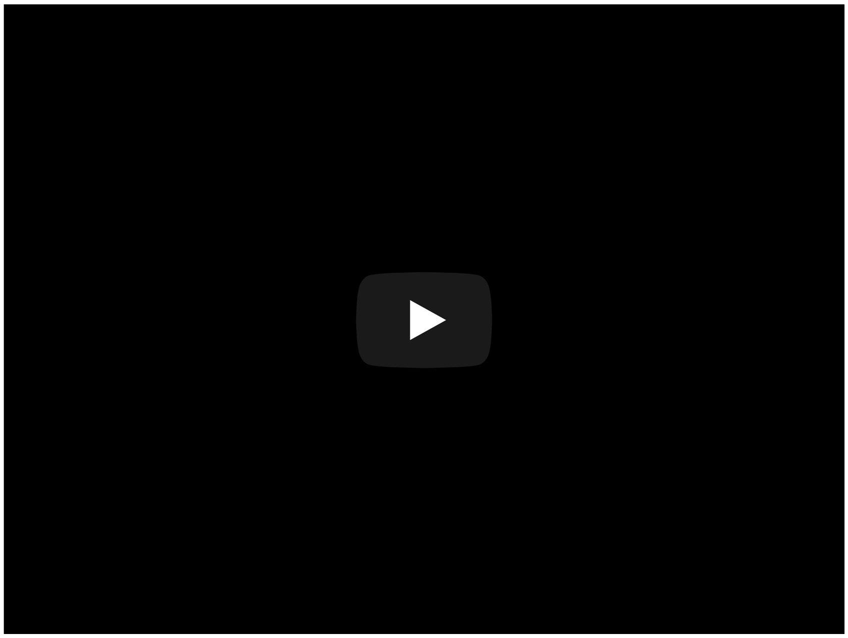
In a quiet room, adjust the tuning control and listen for a station. If several stations are audible, move the diode or antenna taps nearer the earth end (lower numbered turns) of the coil. This increases the set's selectivity and makes it possible to separate stations. In a capital city it should be possible to separate at least nine or ten stations. Optimum tap settings vary across the broadcast band â€“ lower frequency stations are often best received with higher tap settings. In rural areas volume is normally more important than selectivity, so the taps can be moved near the top of the coil.

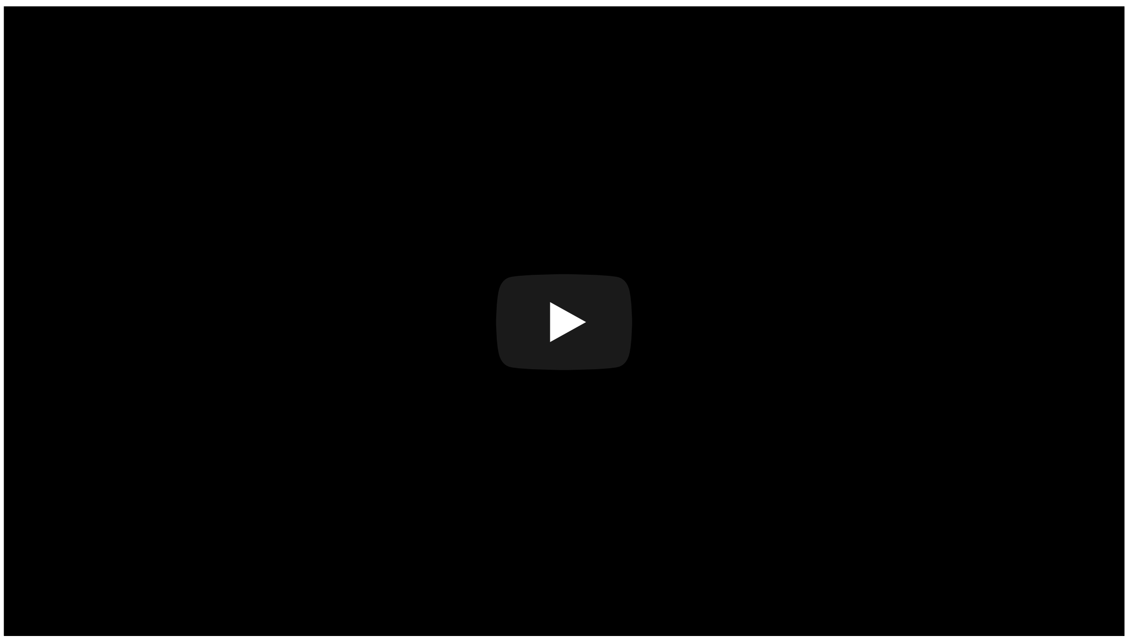
Reception of AM operators on the 1.8 MHz (160 metre) amateur band is possible by moving the capacitor tap lower down the coil, to the 54^{th} or 66^{th} turn. Performance will be well down on a superhet or regenerative receiver, and SSB signals cannot be resolved. Whether you hear amateurs or not depends on your antenna system and the extent of activity from nearby operators. Here in Melbourne 160 metre AM activity includes the Monday to Saturday AM morning net starting at 11am.

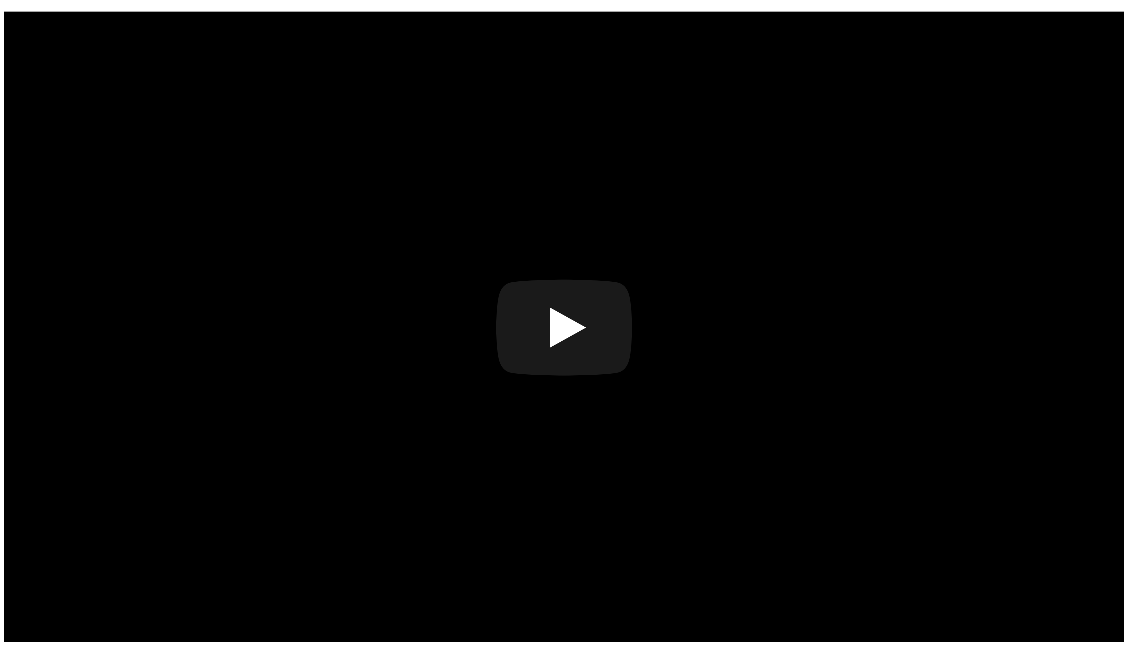
In many areas there are narrowcast stations between the top of the official AM broadcast band and 160 metres. Because of their low power these stations will be weaker than the mainstream broadcasters. However these stations are excellent tests of your receiver and antenna system.

Video demonstrations of this project









Conclusion

A crystal set of moderate complexity has been described. It is the minimum required to provide good reception of local stations in urban and rural areas. However numerous refinements to increase sensitivity, selectivity or audio output can be made. These include:

1. Double tuned circuits (with variable coupling between them) to improve selectivity

2. Use of a tuned trap to null out interfering signals

3. Attention to the construction of coils to provide the highest possible Q

4. Addition of an impedance matching network to provide efficient power transfer between the antenna and the tuned circuit

5. Use of a large loop antenna for the coil to allow reception of signals without an external antenna and nulling of unwanted signals

6. Voltage doubler diode detector circuit using two diodes to increase volume

7. Use of DC bias (from a DC voltage applied to the diode) or RF bias (from a locally generated RF signal on the receiving frequency) to improve sensitivity, or, in the case of the latter, to provide CW and SSB reception.

8. Use of a Q multiplier to increase sensitivity and allow CW and SSB reception.

Should you decide to experiment with these changes, it would be desirable to keep this set as a reference and build a second receiver as a test bed for the experiments.

Obtaining the parts

Suitable parts were discussed in detail above. Many if not all can be bought online, with examples presented below.

Variable capacitor and knob